



Manufacturers of High Temperature & High Vacuum Equipment

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Specification Sheet

Camco Equipment Model: H-COM-1600
Hydrogen / High Vacuum / Inert
Controlled Atmosphere Furnace



Chamber Type	Electropolished Stainless Steel Coldwall, Vertical "Bell" Style
Controlled Atmosphere Types	High Vacuum (Turbo Pumped, 5e-7 Torr ideal Pressure) Positive Pressure Hydrogen Argon Partial-Pressure and Positive-Pressure
Maximum Operating Temperature	1600°C, 75°C per minute maximum ramp rate
Hot Zone Size, Type	11.5" (29 cm) Dia. x 18" (45 cm) H. Nominal All Molybdenum Shields and Rod-Style Element
Thermocouple	Type "C" Tungsten-Rhenium, Control and Overtemp
Equipment Dimensions, Weight	65" (165 cm) W. x 28" (71 cm) D. x 66" (167 cm) H. 1700 lbs (750kg)
Power Requirements, North America	480V 3 Ph. 60A 60 Hz. or 208/240V 3 Ph. 120A 60 Hz
Power Requirements, International	380-415V 3 Ph. 70A 50 Hz.
Gas Requirements	Nitrogen 30 – 60 PSIG, 0-50 LPM Flow [INERT]
	Hydrogen 30 - 60 PSIG, 0-50 LPM Flow [REDUCING]
	Argon/Helium 20 – 60 PSIG, 0-20 LPM Flow [NOBLE]
	CDA 80 – 100 PSIG, <=100 Micron filter [PNEUMATICS]
Cooling Requirements	40 PSIG Max Supply pressure, minimum 4 GPM Minimum 5 Ton (60,000 BTU) Chiller Capacity Maximum 15 PSI Backpressure
Hydrogen Exhaust	Burnoff Column (included), or Must vent from building
Gas Humidifier (Optional) Makeup Water	10-60 PSIG, DI Water, ~1 Gallon (3.7L) per week

Standard Features	Options
850 L/sec. Agilent Turbomolecular Pump 300 L/min. Agilent Dry Foreline Pump - High Vacuum isolation valves - Easy-to-use Touchscreen Controller with 100 Stored Recipes - Mass Flow Controllers for All Process Gasses - Ethernet connectivity - FTP For Scheduled Data Log Collection - Webserver for Remote Monitoring - Modbus TCP for SCADA Implementation - Equipment on casters to roll into place - Survey Thermocouple (1) With Advanced Workload Instructions - Heavy-Duty casters to roll into place (Fits through most doors) - Sight Port for Calibration Melts - Industrial 3-Color Tower Light - Oxygen Sensor and Burnoff Column Fully automatic - One button push starts the run. Automatically runs through recipe with no operator interaction needed beyond loading and unloading.	- Additional Survey Thermocouples – Up to 4 total - Heated Gas Humidifier (Bubbler) - Auxiliary High-Vacuum Ports – For RGA, tube excitement, etc. - High Temperature Furniture – Molybdenum and Tungsten - UPS backup for controllers – maintain furnace runs through short power outages / unstable grid



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Equipment Description

Model H-COM-1600

Hydrogen and High-Vacuum Furnace

For Automatic, Continuous Operation to 1600° C

WorkZone: 11.5" Dia. x 18" H



General machine overview:

Camco furnaces are fully controlled-atmosphere, water-cooled "batch" style furnaces that are meant to process a single load at a time. Once parts are loaded, the user chooses the appropriate recipe for processing the load, and the entire profile is performed automatically. The controller determines when the furnace chamber can be opened safely at the end of the run based on physical and software safety interlocks, relay logic, pressure, and temperature checks. The outside of the water-cooled chamber is safe to touch at any process temperature, and also helps remove heat at the end of each run. Common uses for the machine are high-temperature brazing, sintering, heat treating, and clean firing.

Camco furnaces come standard with an advanced setpoint PID controller with many automation features, and this manual is a guide to the basic functions that users must understand before operating the machine. The controller was developed by Camco Furnace, for Camco furnaces, and is not recommended or supported for use with any other type of furnace or machine.

This machine is designed to heat to **1600°C**. It is capable of operating in a high-vacuum or positive-pressure reducing atmosphere. All process gasses are run through Mass Flow Controllers (MFC) and can also be used for creating a partial pressure environment. Standard gas loadout is Nitrogen (purge), Hydrogen (reducing/flux), and high-purity argon. This furnace is also approved for use with forming gas (H5N) or helium **in place of the argon**.

Base Unit

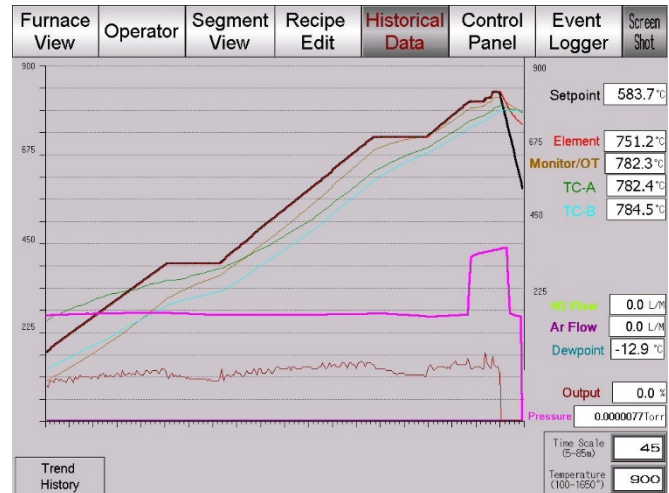
The base unit measures 74 inches wide by 34 inches deep and 90 inches tall with the hoist fully raised. Its' substantial frame is constructed of heavy wall square steel tubing. Service access is readily gained through a hinged steel door and the removable front, side, and rear panels. The plate steel floor within the base unit supports the heating transformers and closes the bottom. Also contained within the base unit is the SCR unit, power components, and other electronics. At the lower right are the atmosphere control module, gas plumbing and cooling water plumbing. The high vacuum turbo pump, roughing pump and manifolds are also located within the right side of the cabinet. In addition, the base frame supports the instrument console and the water-cooled chamber bottom end at a convenient operator height for loading of product. A fan at the rear of the base unit draws cooling air through a replaceable filter element to cool the power control unit and transformer.

A useful feature is the inclusion of recessed heavy-duty casters. The unit is easily rolled into place, and the leveling feet are lowered to immobilize and level the equipment. This unit can fit through a standard door with the chamber and hoist removed. The finish used on this, and all CAMCo equipment is baked powder coating, chosen for its' durability. The stainless steel top skin reduces the possibility of load contamination.

Temperature Control

Multi-stage programmed Ramp & Soak Temperature control (closed-loop PID) and vacuum sequencing are achieved through the use of an IDEC PLC and HMI Touchscreen controller. The software was developed 100% in-house and is fully optimized for Camco Furnaces.

The controller receives its' input signal from a thermocouple located close to the heating element. A second thermocouple is used to monitor the load. A third flexible inonel sheathed type "K" thermocouple can be attached directly to the workload for processes below 1250°C. All inputs are logged by the controller for real-time monitoring as well as observing historical data.



The furnace controller may also use any thermocouple input, or combination of installed thermocouples, to use for the heating loop or for guaranteed soak calculation. This is sometimes called "Cascade" controls and can be changed at any time based on recipes written by the user.

Operation

A robust electric hoist raises the chamber to expose the "hot zone." Work is loaded into the furnace stacked onto a solid molybdenum plate. The hoist then lowers the chamber back down and seals to the bottom flange with pneumatic clamps. One hundred selectable user-programmed thermal profiles may be chosen, and the "start" key pressed. The chamber is then automatically evacuated to below 1 torr where a mandatory leak-back test is performed. Once successful, the furnace continues to turn on the turbo pump for high-vacuum recipes, or backfills with nitrogen to ambient pressure before introducing hydrogen for positive pressure operation.

Chamber/Furnace assembly

The stainless steel water-jacketed chamber bottom end is mounted on the base unit. It is sealed in operation to the chamber by a flange containing a viton "O" ring. The location of the seal is such that it is well cooled and optically baffled assuring long life. The chamber bottom includes work and survey thermocouple feed-throughs, gas admission and exhausts plumbing. It supports the Molybdenum hearth and bottom end stack of six shields via the lower support structure.

The furnace hot-zone is located within the jacketed stainless steel chamber. It incorporates a Molybdenum heating element consisting of twelve sections each supported by high alumina insulators. This surrounds the twenty-inch diameter by forty-eight-inch high work area. A series of Molybdenum cylindrical heat shields in the top and bottom zones surround the elements. This assembly is supported from the inner wall of the chamber.

In addition, the chamber includes the insulated water-cooled power feedthroughs, control thermocouple, sightport, and required cylindrical heat shield support structure. All exposed surfaces of the chamber are safe to touch during the full normal operation of the furnace.

Power Control

Power is proportionally controlled through use of digitally controlled SCR three phase power modules. This unit is phase angle fired control, and includes three phase current limiting made necessary by the strongly positive resistivity coefficient of the heating element. In the event of a power outage at higher temperature, the load temperature would drop to a level where a hard application of heat might thermally shock damage the parts. In this event, an abort relay will trip, and the program will stop and display relevant error messages. Impedance match of the heating elements to the incoming power is accomplished through a pair of conservatively rated 40 KVA transformer driven by SCR power modules.

Vacuum Pumps and Gauges

This machine achieves a high vacuum with two-stage pumping of a mechanical backing “foreline pump” and a turbo-molecular pump. Starting and stopping the turbo pump is handled automatically and must pass several pressure, leak, and interlock checks before operating. All high vacuum pumping is isolated from the chamber with a large-bore gate valve.

A “Roughing” bypass valve exists for pumping around the gate valve and turbo pump. This allows a large amount of pumping to be performed without disturbing the high vacuum components, allowing additional cleanliness and less wear and tear.

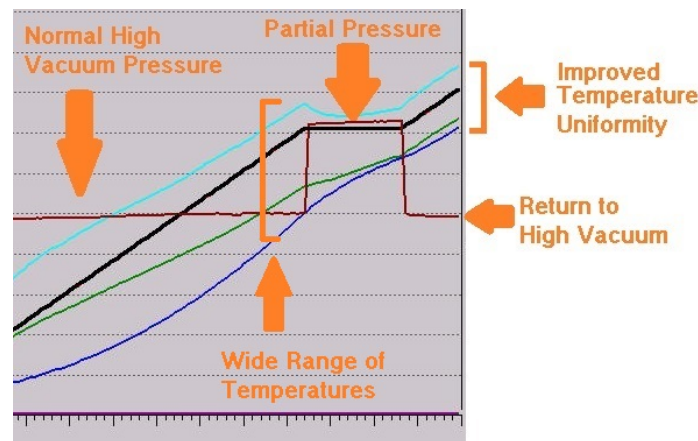
System pressures are read with four different types of gauges: A dual scale pressure transducer (Capacitance manometer and Pirani, 1.0×10^{-3} to 1000 Torr), standard convection gauges (for general chamber and foreline low-pressure, 1.0×10^{-3} to 1.0 torr), and a hot-filament ionization gauge which can accurately measure high vacuum to 1.0×10^{-9} torr. The convection gauges are used for verifying safe conditions to start the turbo pump. The pressure transducer is a gas-agnostic gauge used for accurately measuring higher pressures closer to atmosphere, as well as partial-pressure environments using argon or helium that would otherwise disrupt convection gauges from reading properly.

Partial Pressure Operation: 10^{-4} to 10^{-1} Torr

For certain brazing processes, it is advantageous (or even necessary) to suppress the high-vacuum levels during the actual braze melt. This is due to the vapor point of some alloys becoming very close to the melting point at pressures achievable in the furnace, and the braze alloy risks evaporating if there is even a slight overshoot on the temperature of the furnace reaches. **Please understand the vapor curve of all metals introduced into the furnace** to not accidentally volatilize any parts or braze alloy.

To mitigate this, the furnace allows the recipe to sweep a small amount of high purity noble gas, typically argon, while the turbo pump is still operating to maintain approximately 10^{-2} torr pressure level. This gas is carefully metered with a mass flow controller (MFC) and is highly repeatable. This effectively raises the vapor point of the braze alloy. This state causes some slight stress on the turbo and is only recommended to use during the actual braze melt portion of the recipe and to use a high vacuum for all other times to minimize wear and tear.

Partial pressure can also be performed at higher pressures (between 1 and 5 torr) with a “roughing” valve that will bypass the turbo entirely.



Vacuum Ramp Delay

Logic based on the ion gauge and a set-point declared in the recipe can be used to toggle the recipe timer between RUN and HOLD to keep vacuum level below a programmed vacuum cap setpoint during periods of high gas load (vacuum/heat ramp delay). This feature can be programmed to be active, or non active, anytime throughout the run. The controller will keep track of how often this is triggered while used, and reports it to the event logger and in the run summary at the end of every cycle.

Atmosphere Control

Customer-supplied Hydrogen and Nitrogen gasses are admitted to the chamber through programmed valves and preset flow-meters. An interlock is included which provides for automatic Nitrogen purge in the event of loss of Hydrogen/Nitrogen or chamber pressure. Recipe-set Mass Flow Controllers operate the flow of gasses to achieve the appropriate operating atmosphere.

This option included many additional components and safety features but otherwise does not change the overall size of the machine or work zone. Please inquire for more information.

Standard Features

All Camco machines adhere to relevant standards outlined in the NFPA 86 Standard for Industrial Ovens and Furnaces, among others. Individual certification marks available upon request (CE, CSA, etc.)

These numerous interlocking safety features include but are not limited to:

- Panel Interlocks remove high voltage when open
- Over-temperature Limit Abort
- Adjustable chamber "Safe Access Temperature" to protect operators
- High cabinet temperature
- Chamber exterior temperature
- Low coolant flow
- Low Process Gas pressure switches
- Vacuum cap delay, and various over-pressure abort setpoints
- All turbo pump operation and venting is completely automatic to prevent costly failures
- Many other hard-coded sequences minimize operator and programming errors.

Other quality-of-life features include:

- Digital Mass Flow Controllers (MFCs) for all process gasses, for precise control and totalizing.
- Event and Operator logs for tracking all alarms, major events, and button presses
- User levels to prevent normal operators from modifying recipes or settings
- Screenshot any page at any time to capture and review anomalies
- Ethernet connectivity-
 - Webserver for real-time monitoring
 - FTP for easy retrieval of all data logs
 - Modbus TCP/IP for SCADA implementation
- Front-panel USB for retrieving data logs, screenshots, and backing up recipes
- Free firmware updates when available - no subscription or extra costs

Documentation

Facilities information is supplied to assist in site preparation for installation. An operating manual is supplied with the equipment. Worksheets included in the manual provide a convenient form to depict the desired process for entry into the touchscreen controller. The worksheets also serve as a hard copy of the program. The unit is shipped with an example program stored in memory, depicted by the example worksheet. Wiring and plumbing schematics along with a published spare parts list are also included in the manual. Vendor-supplied manuals for the program controller, overtemp, SCR, vacuum pumps, and other small items are supplied in our documentation.

A recommended startup sequence and relatively simple operation of the furnace are well described and documented in the manual. Most customers can start up the machine without additional on-site support from Camco. However, commissioning and on-site training are always available, and costs can be included in furnace quotations if desired.

While the furnace is a complete, stand-alone unit as described, many applications suggest the inclusion of one or more of the options described in the enclosed data. Other, less commonly ordered options can also be provided. Please inquire for more information.

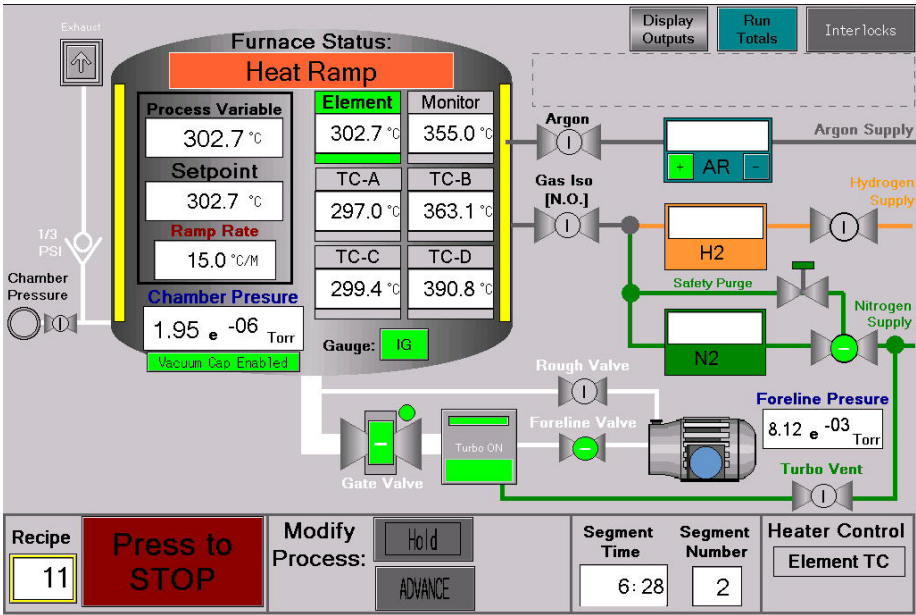
Note: The required process chiller is NOT included in any quotation prices. If your facility requires additional process cooling, Camco can recommend vendors and appropriate units if needed.



Graphical User Interface

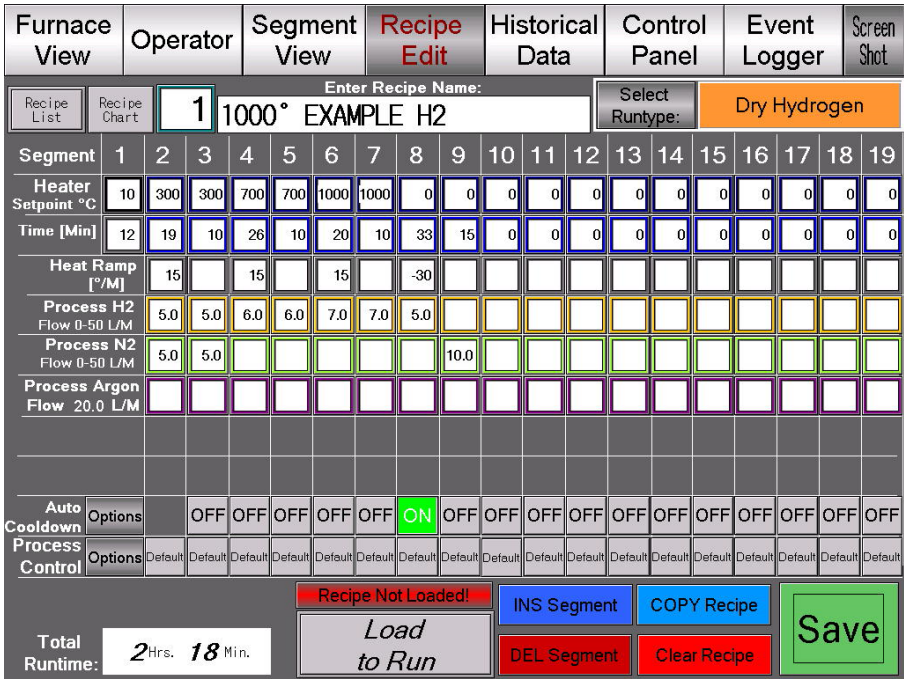
Camco furnace is proud to announce that it has fully launched a standard line of touchscreen HMI/PLC controllers for all of its furnaces. These new components boast many advancements and quality-of-life upgrades compared to their previous controller schema. Most major features are now available standard and always without subscriptions or hidden costs. The intuitive user interface shows current furnace performance and the state of all components to take any guesswork out of the furnace operation.

(The following screens depict a standard combination high vacuum and hydrogen furnace - All furnaces are similar, but this may not be the exact interface for the information pack this is attached to)



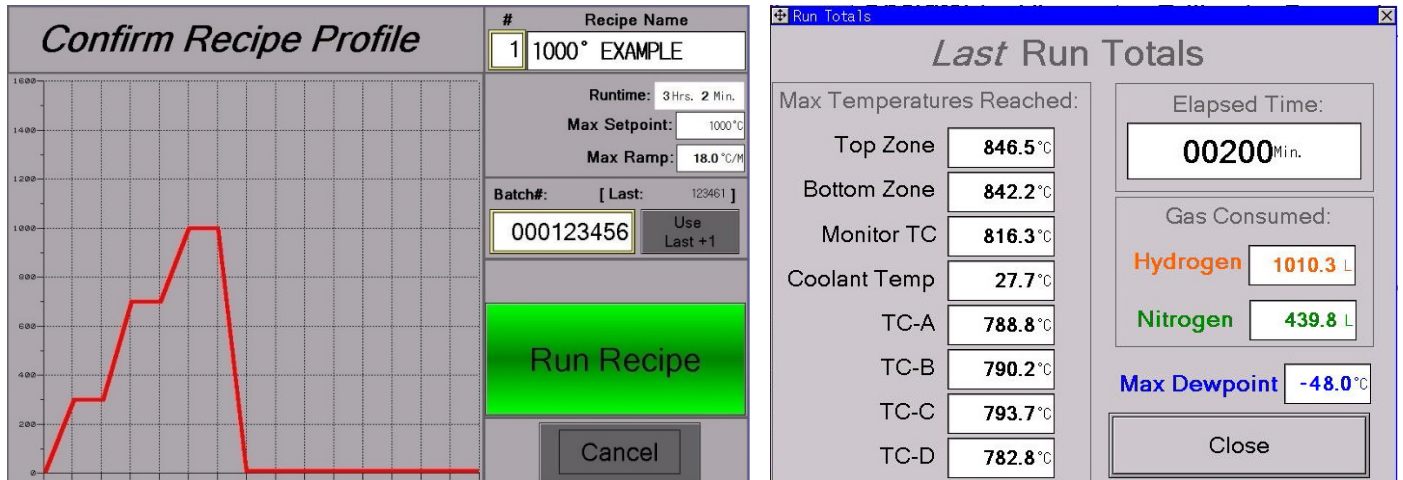
Easy Recipe Creating

Create segment-based recipes using a temperature setpoint and then input either time or ramp rate. All relevant events and inputs are displayed on one page to easily see at a glance what the entire profile will do. Events that are not relevant to the recipe runtime are hidden to remove screen clutter and prevent invalid recipes from being created.



Helpful tools for Operators and Process Engineers

Users are presented with a Recipe Confirmation page before the furnace can be run to help prevent incorrect profiles from being used. Batch numbers are required for data logging but can be easily integrated into any existing downstream processing. Current and last run totals are kept track of for quick summaries including some of the most relevant data points.



Multiple options for setting special control action to the heating loop - part controls and temperature triggers using different methods of workload calculation for highly customizable recipes. An easy-to-use software-enabled work limit prevents parts from melting or reaching otherwise problematic temperatures.

Built-in preventative maintenance tracker simplifies monitoring commonly serviced items, their intervals, and current conditions.

The image shows two software interface windows. The left window, titled "Select TC(s) and Control Action", has a green checkmark icon and a note: "Note: These settings are only for the recipe being edited". It includes sections for "Work Load Calculation" (TC Average, Lowest Input, Highest Input), "Control Thermocouples:" (Element TC(s), Monitor/Overtemp), "Survey Thermocouples:" (A, B, C, D), "Control Action:" (Part Control, Load Trigger Advance), "Load Limit:" (1000.0 °C), and "Part Control PID Set:" (1, 2, 3). A "Confirm" button is at the bottom right. The right window is a maintenance tracker with columns for "Hours Since Last Service:", "Threshold", and "Condition". It lists various items: Exhaust Check Valve, Rough Pump Service, Panel Fan Filter, Heating Elements, Hot Zone Clean Fire, Oxygen Sensor, Element TC, Monitor/Overtemp TC, and Survey TC(s). Each item has a value in the "Hours Since Last Service:" column, a threshold in the "Threshold" column, and a "Condition" (all are "Normal"). A "RESET" button is next to each item. At the bottom, there are fields for "TOTAL RUN CYCLES:" (8) and "Total Runtime:" (25.11), with a "Close" button.

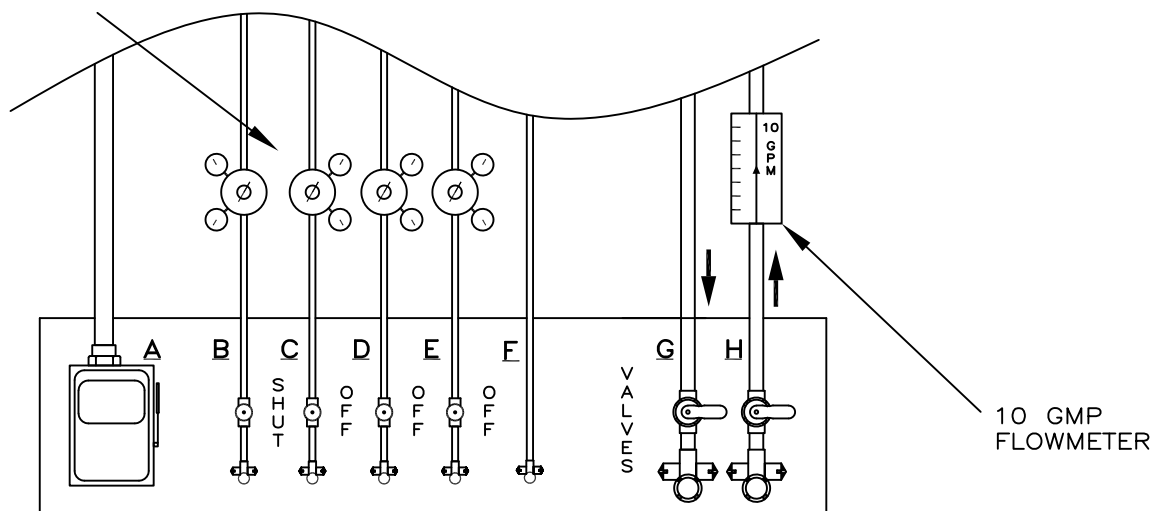
Many other helpful graphical popups and operator pages have been created specifically for Camco equipment by long-time Camco Engineers. Please inquire if you are interested in a remote tech demo or more information on the software.

REV.	DATE	DESCRIPTION
A	9/23/21	UPDATED

UTILITIES PREPARED BY CUSTOMER AS SHOWN:

A: 60A. @ 480 OR 150A. @ 220V. 60 Hz 3 PHASE DISCONNECT.	
B: NITROGEN, 30 TO 50 PSIG AT A MAXIMUM FLOW OF 50 LPM	1/4" SWAGELOK
C: HYDROGEN, 30 TO 50 PSIG AT A MAXIMUM FLOW OF 50 LPM	3/8" SWAGELOK
D: ARGON, 30 TO 50 PSIG AT A MAXIMUM FLOW OF 20 LPM	1/4" SWAGELOK
E: CDA, 80 TO 100 PSIG AT A MAXIMUM FLOW OF 50 SCFH	1/4" SWAGELOK
F: EXHAUST PIPE THRU ROOF (IF NO BURN-OFF)	1/2" FPT MINIMUM
G: COOLING WATER SUPPLY; 40 PSIG MAX AT 5 GPM	1/2" FPT
H: COOLING WATER RETURN: 15 PSI MAX BACKPRESSURE	1/2" FPT

LINE PRESSURE REGULATORS



SUGGESTED UTILITY PANEL LAYOUT

HEAT LOAD: 60.000 BTU (5 TON)

FOR CHILLER CALCULATION

SUPPLY WATER TEMP 18–25°C

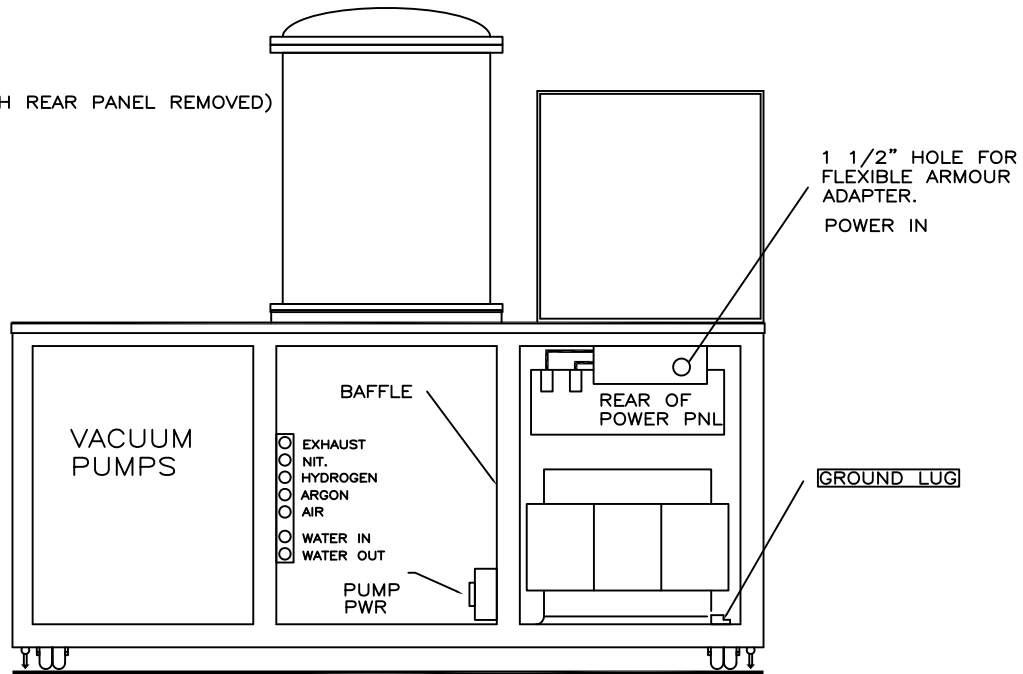
NOTE: (MAX. BACK PRESSURE 15 PSI AT 4 GPM)

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H-COM	785	TOL'S EXCPT AS NOTED	DRN.BY: PAB	 Concepts & Methods Company, Inc.		
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USED ON TASK	FWO	.XXXX ±.0005	FINISH:	TITLE: FACILITY PREP		
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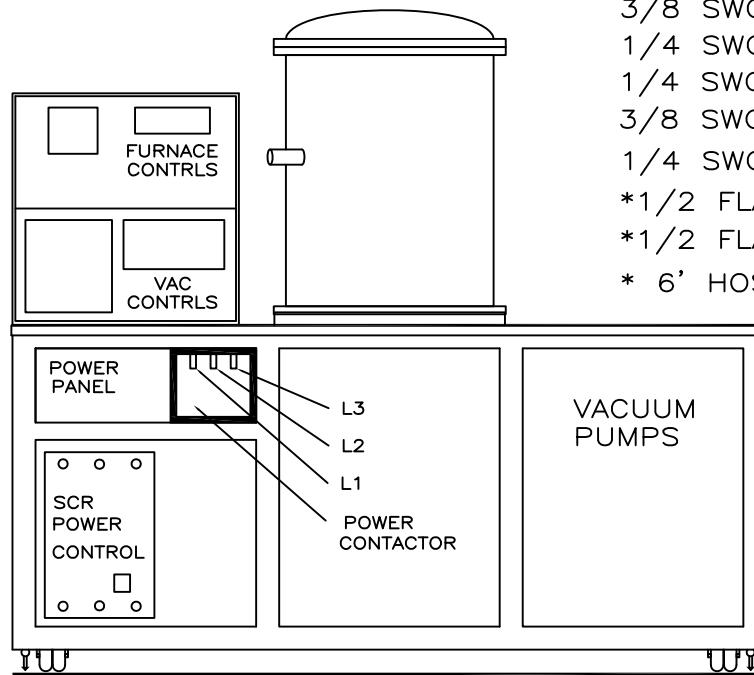
REV.	DATE	DESCRIPTION

(REAR VIEW WITH REAR PANEL REMOVED)



GAS CONNECTIONS

- 3/8 SWGLK EXHAUST
- 1/4 SWGLK NIT.
- 1/4 SWGLK ARGON
- 3/8 SWGLK HYDROGEN
- 1/4 SWGLK AIR
- *1/2 FLARE WATER IN
- *1/2 FLARE WATER OUT
- * 6' HOSES PROVIDED

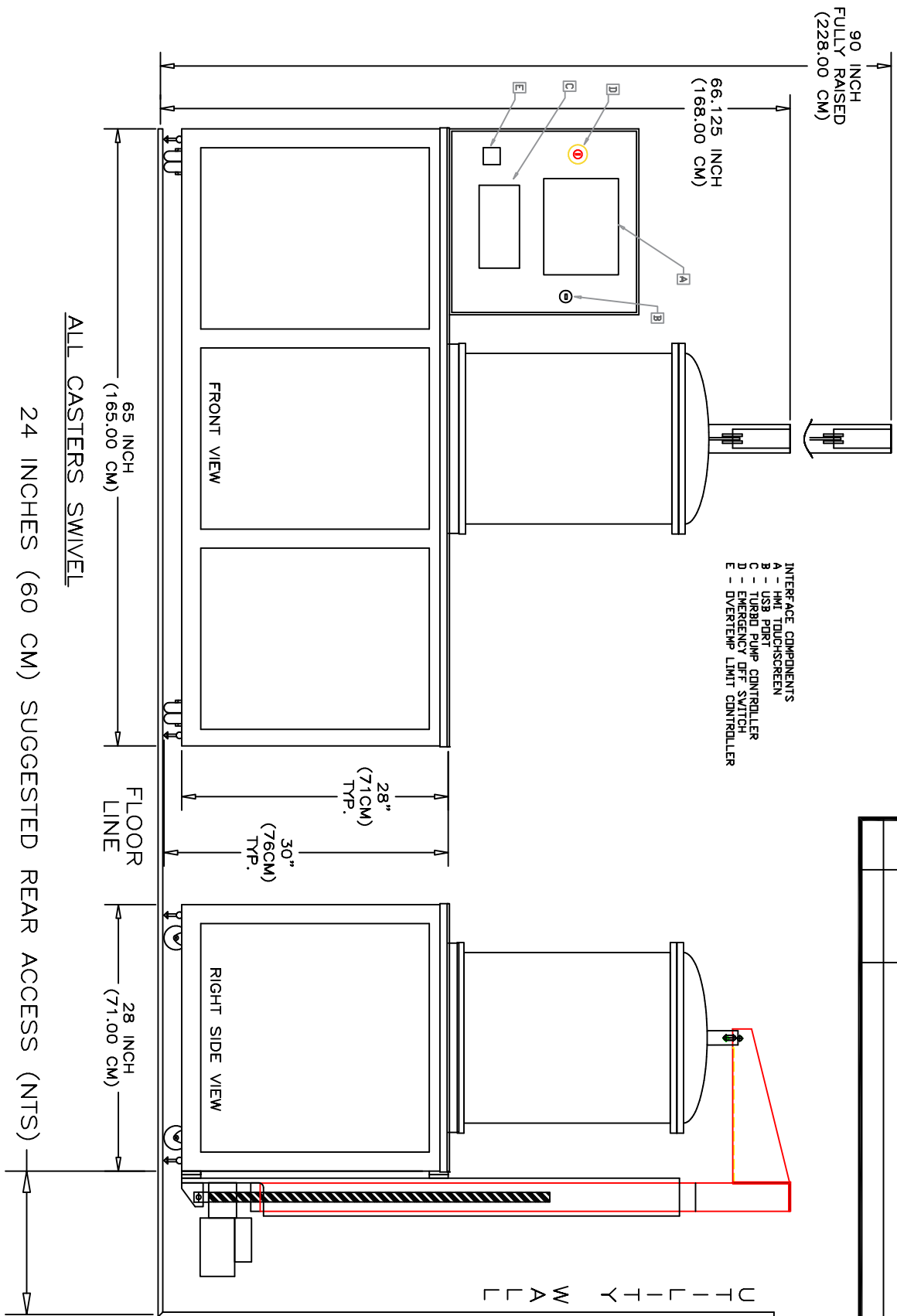


(FRONT VIEW WITH LEFT FRONT PANEL REMOVED)

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H-COM	696	TOL'S EXCPT AS NOTED	DRN.BY: T BARULICH	 Concepts & Methods Company, Inc.		
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USED ON TASK	FWO	.XXXX ±.0005	FINISH:	TITLE: FACILITY PREP GAS AND PWR	DWG.NO: 89873	SHEET 5 OF 7
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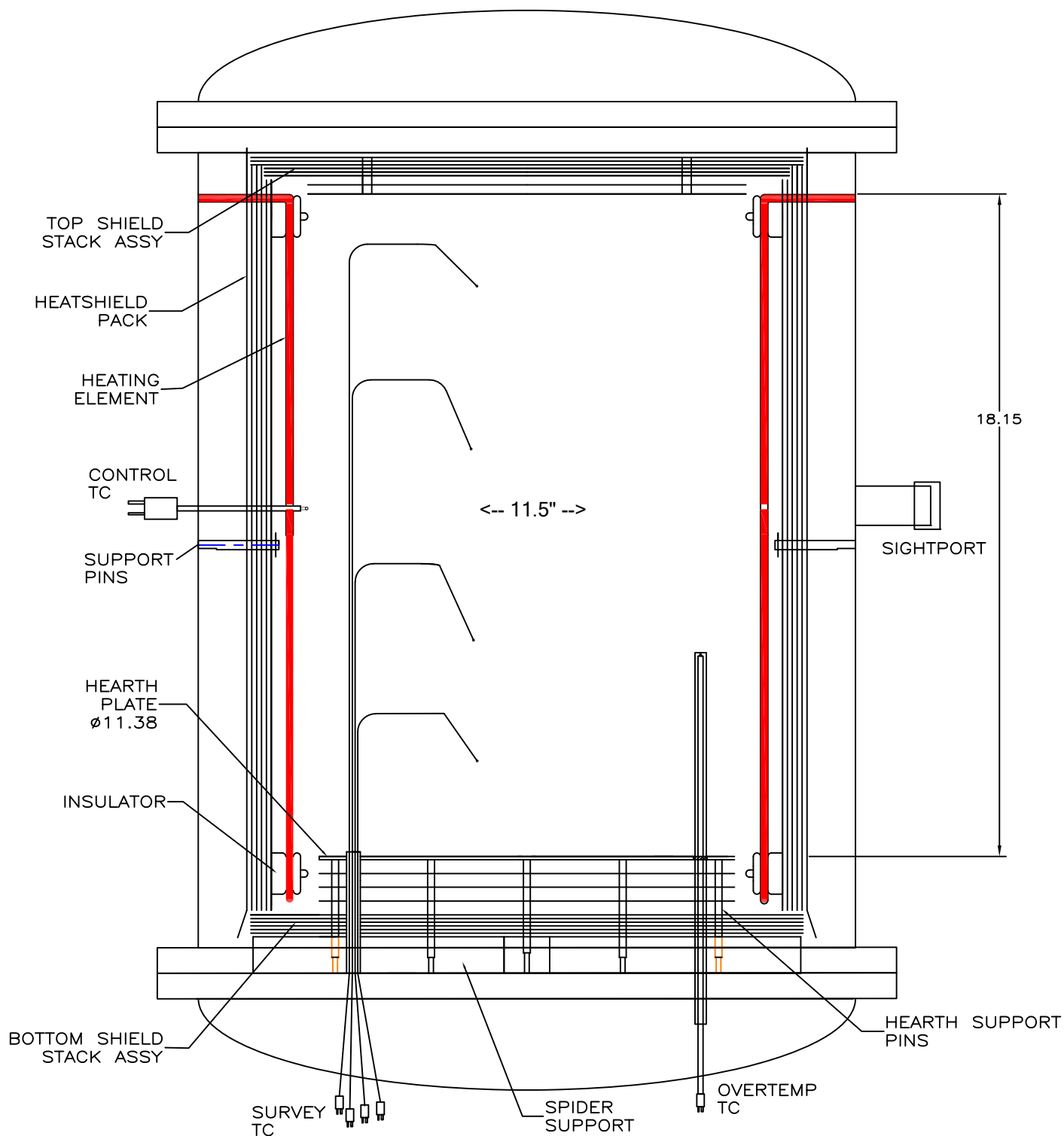
REV.	DATE	DESCRIPTION



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TOL'S EXCPT AS NOTED		DRN.BY: T BARULICH		 Concepts & Methods Company, Inc.	
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.XXXX ±.0005		FINISH:		DWG.NO: 89755	
USED ON TASK		FWO		SHEET 3 OF 6	
H-COM		626		REV:	
H-VAC					

REV.	DATE	DESCRIPTION
A	9-24-18	REMOVE RACK ASSY, ADD NOTES



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H-FURNACE	681	TOL'S EXCPT AS NOTED	DRN.BY: T BARULICH	 Concepts & Methods Company, Inc.		
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		.XXX $\pm .005$	MAT:			
USED ON TASK	FWO	.XXXX $\pm .0005$	FINISH:	TITLE: H-CHAMBER LAYOUT		
		ANGLES $\pm 1/2^\circ$			DWG.NO: 89755	SHEET 1 OF 6
				REV: A		